Cavity QED and Confined Phonons in Semiconductor Quantum Dots

Hailin Wang, University of Oregon, DMR-0201784

Robust electron spin coherence provides an ideal platform for pursuing optical manipulation and control of quantum coherences in semiconductors and for developing quantum coherence based semiconductor devices. A central issue in these endeavors is to understand how the spin coherence contributes to coherent optical processes. In a well-designed quantum beat study, we found surprisingly that the manifestation of electron spin coherence in semiconductors differed fundamentally from that in an atomic system.

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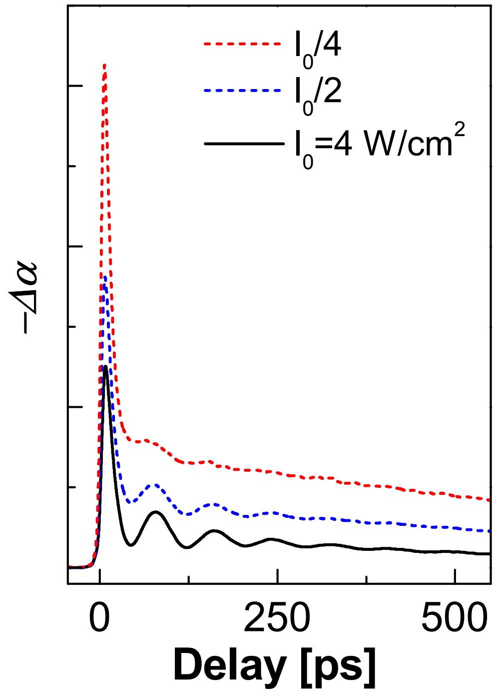

Differential absorption in a GaAs quantum well shows that the amplitude of the quantum beats from electron spin coherence increases with increasing probe intensity. For an atomic system, one would expect the amplitude to be independent of (or decrease with) the probe intensity.

In a well-designed quantum beat spectroscopy with spectrally narrow pulses, we have been able to separate contributions from delocalized excitons in a quantum well from excitons that are localized by interface disorders. We show that quantum beats from electron spin coherence associated with the delocalized excitons vanish at low probe intensity, but emerges with increasing probe intensity. These behaviors, which are completely unexpected, reveal how coherent nonlinear optical response of electron spins in semiconductors arises from underlying manybody Coulomb interactions. Previous experimental studies in this area have used spectrally broad laser pulses. As a result, the experimental results are masked by a dominant contribution from localized excitons, which in many ways behave like an atomic system.

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Education:

Four graduate students are now participating in the research efforts funded by NSF. Two students, Sasha Kruger and Shannon O'Neil are female. The other two students are Phedon Palinginis and Yumin Shen. Phedon has successfully defended his PhD thesis earlier this year and is taking a postdoc position at UC Berkeley. An earlier participant of this project, Mark Phillips, is now leading research efforts in this area at Sandia National Labs.

Societal Impact:

The understanding of how electron spin coherence contributes to coherent optical processes in semiconductors opens the way for the use of the exceptionally robust spin coherence in both classical and quantum communication, e.g. optical buffers, quantum memory of photons, and generation of entangled photon pairs. We are also interested in using the spin coherence for cavity QED studies.